

UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

A NEW SELECTIVE SPRAY FOR THE CONTROL OF CERTAIN WEEDS

W. A. WESTGATE and R. N. RAYNOR

BULLETIN 634

February, 1940

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

CONTENTS

	PAGE
Introduction.....	3
Scope of present investigations.....	3
Principles of the selective action.....	4
Economics of spraying.....	5
Method of taking yield data.....	7
Discussion of yield data.....	7
The action of Sinox.....	12
Factors influencing the effectiveness of Sinox.....	13
Stage of growth of weed.....	13
Conditions under which plants grow.....	14
Temperature and humidity.....	15
Rain, fog, and dew.....	15
Spray pressure.....	16
Dosage with ground sprayers.....	17
Dosage with airplane application.....	18
Tolerance of grain and flax to Sinox.....	19
Use of Sinox other than with cereals and flax.....	21
Transplanted onions.....	21
Seedling onions.....	21
Peas.....	21
Corn.....	22
Alfalfa.....	22
Roadsides, fence lines, and pastures.....	23
Lawns.....	24
Deep-rooted perennials and puncture vine.....	25
Effect of Sinox on the soil.....	28
Equipment for applying Sinox.....	29
Pump.....	29
Boom.....	31
Nozzles and spray disks.....	31
Screens.....	34
Tank.....	34
Agitator.....	34
Cost of applying Sinox.....	34
Summary.....	35
Acknowledgments.....	36

A NEW SELECTIVE SPRAY FOR THE CONTROL OF CERTAIN WEEDS^{1, 2}

W. A. WESTGATE³ AND R. N. RAYNOR⁴

INTRODUCTION

A PREPARATION consisting of 30 per cent sodium dinitro-ortho-cresylate and 70 per cent water was developed as a weed spray in France in 1933 under the proprietary name Sinox. As the chemical name is unwieldy, and also likely to be confused with chemicals having similar names but other uses, it seems desirable to use the proprietary name in this bulletin.

Since the development of Sinox in 1933, it has been used throughout central Europe and in England as a selective spray in cereals and flax. In this country it was first used in 1938-39. During that season about 12,000 acres of grain and flax were sprayed in California, of which approximately 2,000 were treated by means of airplanes and 10,000 by ground sprayers. It was used primarily for controlling wild radish (*Raphanus sativus*) in the delta region of San Joaquin and Contra Costa counties. One thousand acres were sprayed near Tulalake, Siskiyou County, for the control of wild mustard (*Brassica arvensis*).

Sodium dinitro-ortho-cresylate is a basic dyestuff made from coal tar. The water contained in the proprietary mixture is necessary in the manufacturing process and serves to render the material noninflammable. The preparation is noncorrosive and relatively nonpoisonous in comparison with arsenicals and other heavy metals, though in large doses it is toxic if taken internally. Used as a spray, it is noninflammable and nonhazardous on clothing or foliage. The dried product is highly inflammable, however, and users must not allow the opened cans to dry out. Equipment should be washed off after use.

SCOPE OF PRESENT INVESTIGATIONS

The investigations reported herein comprise two seasons' work in testing the efficacy of the chemical under California conditions and in developing suitable concentrations and equipment for its application. During

¹ Received for publication November 16, 1939.

² This project was partially supported by the Crop Protection Institute, through funds contributed by Standard Agricultural Chemicals, Inc., Hoboken, New Jersey.

³ Formerly Crop Protection Institute Fellow; resigned December 1, 1939.

⁴ Associate in the Experiment Station.

the first, done in the winter and spring of 1938, numerous plots in grain, flax, and onions were treated with a knapsack sprayer. These plots were 1 square rod in area. There were a few applications with power equipment in grain and flax located in San Joaquin and Yolo counties. Although few yield records were taken at that time, the practicability of the material as a selective spray was demonstrated.

In 1938-39 a power sprayer was used exclusively for the field spraying; and over 700 plots were sprayed, 120 different field conditions being represented. Each plot, except those on lawns, represents a sprayed strip 16 feet wide and 200 to 300 feet long. Under each of the 120 field conditions, several different plot applications were made, with various concentrations and volumes per acre. Usually the most heavily weed-infested areas were selected for the plot locations.

PRINCIPLES OF THE SELECTIVE ACTION

The question is often asked, How can one kill the weeds in various field crops, such as grain, flax, alfalfa, and onions, without destroying the crop itself? The answer is, in part, that the foliage of these crops is not easily wetted by an aqueous solution. The spray will almost entirely run off the leaves and stems of such plants as flax, alfalfa, and peas; the leaves of cereals, corn, and onions. Although a few droplets may adhere, these will be spherical with a very small area in actual contact with the plant. The leaves of various common annual weeds such as wild mustard, prickly or Chinese lettuce (*Lactuca scariola*), wild radish, and yellow star thistle (*Centaurea solstitialis*) are easily wetted by the spray; and, because of the exposed broad-leaved surface of the weeds, considerable spray comes in contact with the plant. Other weeds, such as fireweed or fiddleneck (*Amsinckia* spp.), are not easily wetted; but the numerous hairs on their stems and leaves will hold relatively large amounts of the spray. Wild oats (*Avena fatua*) and other grasses growing as weeds in flax and onions are not controlled. Another reason why corn, onions, and cereals are not ordinarily injured by the spray is that their growing points are protected by leaves, whereas those of the common broad-leaved weeds are exposed. Although the leaves of cereals may be slightly injured, the plant is not damaged permanently.

Some weeds—for example knotweed (*Polygonum aviculare*), pale smartweed (*Polygonum lapathifolium*), common chickweed (*Stellaria media*), and lamb's-quarters (*Chenopodium album*)—have only their stems wetted; and Sinox, to be effective, must be applied at an early stage when the stems are very tender.

Crabgrass (*Digitaria sanguinalis*) in a bluegrass lawn can be con-

trolled without permanent injury to the sod if sprayed with Sinox when the seeds first germinate. The seedlings are tender and yield to the treatment, whereas the bluegrass, being a perennial, is more resistant.

ECONOMICS OF SPRAYING

The primary object of weed control is to increase yields at a profit to the grower. It costs just as much to prepare the soil for a low yield as for a high one, and it often costs more to harvest the lower-yielding acreage.

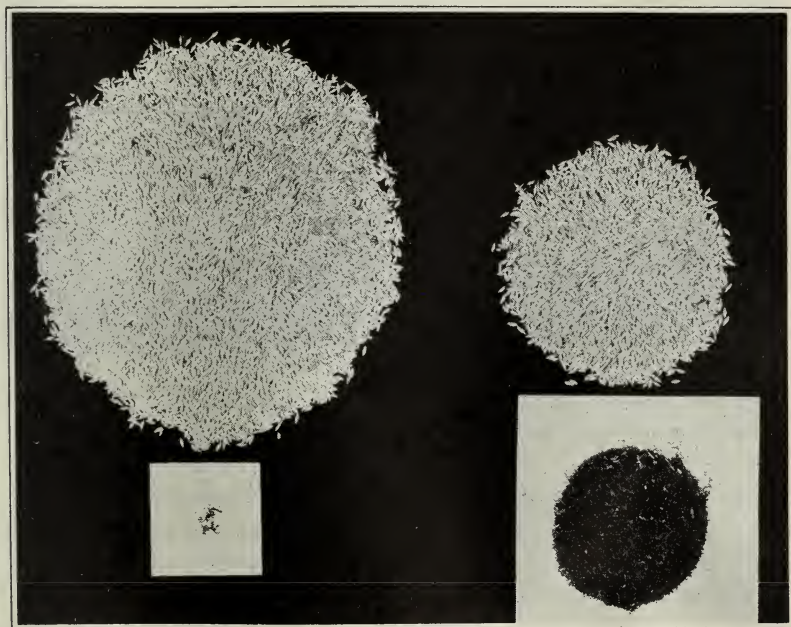


Fig. 1.—Comparative yields of barley and mustard seed from sprayed (left) and unsprayed plots (right). As noted in the insert at the lower left the proportion of weed seed to the barley in the sprayed plots is insignificant. Data on the yields are presented in table 2.

When, therefore, the question of spraying is one of economics, its cost must be at least compensated for by increased returns from the land. For example, if the cost of spraying a barley field is \$3.00 per acre, the grower must increase his yield at least 300 pounds when barley is selling at \$1.00 per 100 pounds. Any increase in yield over 300 pounds would, in this case, represent a net gain. Savings in operation costs due to clean fields are an added gain. Such examples are often encountered in actual practice. Some of the common annual weeds, such as wild mustard, wild radish, fireweed, and yellow star thistle, reduce yields and lower the

rental value of the land. In flax-seed production, for example, growers are often limited in the choice of suitable land because of these weeds. Dockage when the grain or flax is sold results from the large percentage of weed seeds and pods mixed with the crop seed, as is illustrated in figures 1 and 2. When weeds appear in such crops as oats, wheat, barley, and

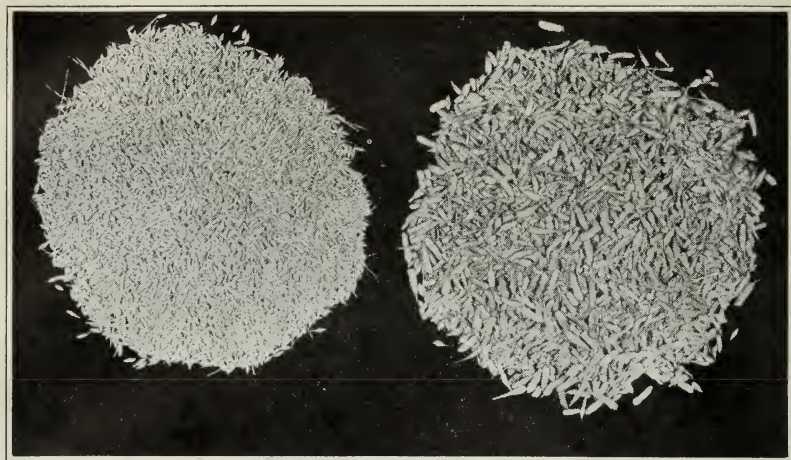


Fig. 2.—Samples of barley from sprayed (left) and unsprayed plots (right) showing control of wild radish. Note the abundance of radish pods or "peanuts" which passed through the thresher in the untreated sample.

flax, the added load on the machinery and the slowing up of the harvesting are sources of loss. Wild radish, yellow star thistle, and pale smartweed often remain green longer and dry more slowly than the grain with which they grow. Such weeds, if present in a crop, not only delay its drying and curing, but sometimes necessitate windrowing as an added operation. Some weeds, such as volunteer common vetch (*Vicia sativa*), have climbing stems that pull down the grain, which causes loss and makes harvesting difficult.

Another objective of spraying is the eventual cleaning up of the land and preventing spread. Mustard and radish seeds are known to retain their germinating power for over twenty years after they have been buried in the soil. Presumably, though there is little definite information, some four to six years are required to free the soil of these weed seeds where an effective annual program of spraying, cultivation, or summer fallowing has been followed. Spraying for a few years should reduce most infestations to the point where hand-pulling will be a more economical method of completing eradication.

METHOD OF TAKING YIELD DATA

In the determination of yield data, randomized one-thousandth-acre quadrats were harvested and threshed from each sprayed and unsprayed plot. The sampling was confined to areas that apparently represented the average condition of the plots as regards soil conditions and as regards the presence or absence of competing weeds other than those under study. Thus, samples were not taken from alkali spots nor from areas heavily infested with wild morning-glory. Since sprayed and unsprayed plots always adjoined and ran parallel to each other in the field, a system of paired sampling was adhered to. Each time a quadrat was harvested from a sprayed area, an unsprayed quadrat was taken directly adjacent. Usually five paired quadrats or samples were taken for each dosage. Where the yield differences between the sprayed and unsprayed plots were not obvious, seven paired samples were taken instead of five. Weed counts were made on each quadrat at the time of harvesting. Yield and weed control data are presented in tables 1 and 2.

DISCUSSION OF YIELD DATA

As tables 1 and 2 illustrate, yields of grain and flax can be increased considerably by controlling the common annual broad-leaved weeds with a Sinox spray. As would be expected, the percentage increase of sprayed plots over unsprayed is generally in an approximate proportion to the degree of infestation. Sometimes, however, a few weed plants, if they can reach a considerable size in competition with the crop, may do as much damage as numerous smaller weed plants, or even more. It will be noted in table 2 that a very heavy infestation of wild mustard in wheat on the Phillips Estate, Brentwood, almost completely choked out the grain. These plots are shown in figure 3. In grain the infestation of wild mustard must be rather heavy to cut yields greatly, whereas in flax a smaller number of plants per unit area will cause much damage. This is illustrated by the differences in yield between treated and untreated plots, cited in table 1 and pictured in figures 4 and 5. Wild radish, having a branching habit, will cause more damage per plant than wild mustard.

Particularly interesting are the tables on fireweed control. Fireweed is a serious pest in flax throughout the San Joaquin Valley, cutting down yields considerably (table 1 and fig. 6). Infestations as dense as that illustrated in figure 7 are not uncommon. On the Ohlendorf field (table 1 and figs. 6 and 7) an 81 to 88 per cent control of fireweed in-

TABLE 1
YIELD INCREASE FROM CONTROLLING WEEDS IN PUNJAB FLAX

Ranch and location	Sinox concentra- tion	Volume, gallons per acre	Weeds	Number of weeds per 1/1000 acre		Control, per cent	Yield, bushels per acre		
				Untreated	Treated		Untreated	Treated	Increase
Aitken Ranch, Tracy.....	1:50	50	Fireweed	221	6	97	5.5	19.9	14.4
	1:80	80	Fireweed	145	8	95	5.2	17.8	12.6
	1:80	120	{ Fireweed Wild mustard	353 9	2	99	7.7	30.6*	22.9
	1:120	80	{ Fireweed Wild mustard	32 296	7 0	79	3.9	16.4	12.5
	1:120	100	{ Fireweed Wild mustard	285 4	35 0	100	8.6	17.6	9.0
	1:120	100	{ Fireweed Wild mustard	32 195	18 0	44	8.5	20.6	12.1
	1:120	140	{ Fireweed Wild mustard	32 195	3 0	90	8.5	18.3	9.8
	1:80	55	Fireweed	595	85	86	10.9	27.1	16.2
	1:80	85	Fireweed	425	43	90	11.2	27.1	15.9
	1:53	80	Fireweed	489	62	88	3.4	16.6	13.2
Ohlendorf field, Tracy.....	1:80	80	Fireweed	313	45	86	6.8	19.8	13.0
	1:100	125	Fireweed	264	49	81	4.4	13.6	8.8
Tarke Ranch, Meridian.....	1:100	100	Wild mustard	143	0	100	4.9	21.8	16.9
California Packing Corporation, Stockton.....	1:80	80	{ Wild mustard Prickly lettuce	68 19	0 0	100	12.7	45.7	33.0
	1:100	100	{ Wild mustard Prickly lettuce	113 6	0 0	100	9.4	43.6	34.2

* Both sprayed and unsprayed plots were located on an old corral site.

TABLE 2
YIELD INCREASES FROM CONTROLLING WEEDS IN CEREALS

Crop and variety	Ranch and location	Sinox concentra- tion	Volume, gallons per acre	Weeds	Number of weeds per 1/1000 acre		Control, per cent	Yield, pounds per acre		
					Untreated	Treated		Untreated	Treated	Increase
Wheat Special Big Club	Lee A. Phillips Estate, Brentwood	{ 1:100 1:120 }	100	Wild mustard	554	0	100	26	1,870	1,844
			120	Wild mustard	599	0	100	26	2,570	2,544
Federation	Cone Ranch, Red Bluff.....	1:120	90	{ Wild mustard Fireweed Yellowstar thistle }	41	0	99	1,700	2,240	540
				119	3	98				
Galgalos	J. Bush, Tullake.....	{ 1:50 1:120 }	57	Black mustard	231	0	99	1,980	4,050	2,070
			100	Black mustard	231	0	99	1,980	3,910	1,930
Oats Red	Sleepy Hollow Ranch, Sears Point.	1:100	100	{ Common yellow mustard Wild mustard Common vetch }	68	0	100	364*	1,694	1,330
				37	0	100				
Barley Atlas	J. W. Boulton, Stockton.....	1:80	80	Wild radish	19	0	98	2,150	2,900	750
				Yellowstar thistle	623	62	90	1,070	2,190	1,120
California Common	S. Cronin, Dublin.....	1:100	120							
Vaughn	J. Shearer, Sycamore.....	1:120	120	Wild mustard	115	3	98	980	2,000	1,020
Hannchen	J. Bush, Tullake.....	{ 1:50 1:100 }	50	Wild mustard	652	1	99	1,830	4,390	2,560
			70	Wild mustard	413	0	99	2,590	3,760	1,170
Hannchen	J. Kandra, Tullake.....	1:50	60	Wild mustard	579	207	66†	3,340	4,170	830
Hannchen	W. P. Hooper, Tullake.....	{ 1:80 1:120 }	80	Wild mustard	355	0	99	2,700	4,000	1,300
			80	Wild mustard	117	0	100	3,570	3,990	420
Hannchen	C. C. Spears, Tullake.....	1:80	80	Wild mustard	491	0	100	2,950	4,720	1,770

* The untreated plots were badly lodged, making it difficult to harvest and causing loss by the shelling out of the oats.

† These plants not killed were much stunted by the spray and did not grow above the grain.

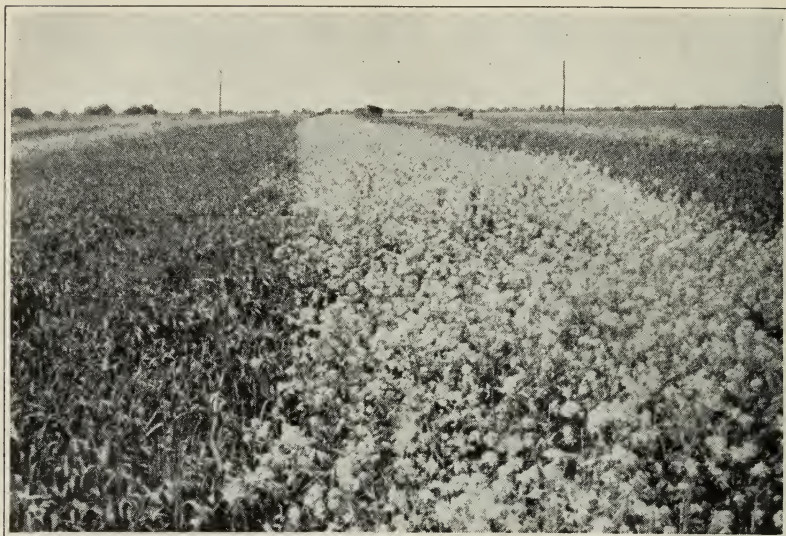


Fig. 3.—Sprayed (left) and unsprayed strips (center) in a wheat field near Brentwood, California. Here Sinox has practically eliminated mustard from the growing grain.



Fig. 4.—Control of wild mustard in flax. Note flax in bloom in the treated strip (center), and the complete absence of flax in the untreated strip at the left.



Fig. 5.—Left, comparative yield of flax from sprayed plots (21.8 bu. per acre); right, unsprayed plots (4.9 bu. per acre) infested with wild mustard.



Fig. 6.—Flax from sprayed (left) and unsprayed plots (right) showing results of the control of fireweed.

creased the yield of the sprayed over unsprayed an average of 340 per cent. This degree of control came about over a period of several weeks. In this test, evidently, the important factor as regards yield is the retarding or setting back of the fireweed by the spray, permitting the flax to overcome competition with the weed. The same principle applies to grain



Fig. 7.—Plots showing the control of fireweed in flax. Note the flax in bloom in the sprayed area at the right.

where wild mustard and wild radish are the principal weeds. Often it is not practical to effect an actual 100 per cent kill. As will be noted, in table 2, a 66 per cent control of wild mustard on the Kandra field caused an increased yield of 830 pounds of barley per acre.

THE ACTION OF SINOX

Sinox does not destroy the weed in a manner as the so-called "burning" of sulfuric acid. The action might, rather, be described as a slower poisoning process that normally results in the complete rotting of the plant attacked. Though the nature of the action is not fully understood, it is apparently related to the staining or dyeing property of the chemical.

The rate of action varies considerably since it depends on several factors, such as temperature, dosage, and rate of evaporation, and upon the species, stage of growth, and condition of the weed. For convenience in interpreting field results, one may classify the action as fast or slow according to the conditions in the field that determine its rate of action at the time the spray is applied. The action is fast on young, succulent

mustard and wild radish growing under normal conditions of soil moisture and at temperatures above approximately 50° Fahrenheit. Light-colored or translucent spots will appear on the leaves within a few minutes to a few hours after the application, according to the temperature. These areas grow larger and finally cause the complete wilting down of the weed within three to five days. Under cold or extremely dry conditions and on fireweed generally, the action is slow and the translucent spots may not appear at all. Under these conditions the plants do not wilt down as they do with fast action; rather, there is a gradual devitalizing of the weed, permitting the crop to outgrow the weed. In some instances the weeds may at last be completely destroyed by drying up, while in other cases some may remain as insignificant stunted plants. Large, succulent plants of mustard, radish, and fireweed may be weakened and die from fungus attack resulting secondarily from Sinox treatment.

FACTORS INFLUENCING THE EFFECTIVENESS OF SINOX

Stage of Growth of Weed.—Usually the best time to spray any weed is when it is young and in the rosette stage. Less material is required when the weeds are small than after they have developed a greater resistance by aging. When they are young and tender, the spray penetrates the leaf more rapidly; and, in consequence, there is less danger of adverse conditions' preventing good results. The ideal stage for spraying wild mustard is when it has developed three to seven true leaves or is 3 to 7 inches high. This pest has, however, been successfully controlled up to the flower stage. Figure 8 shows the range in the development of both the mustard and the grain at which spraying is most effective. Wild radish, common yellow mustard (*Brassica campestris*), and black mustard (*Brassica nigra*) growing in grain should be sprayed at the same corresponding stages as for the common wild mustard illustrated in the figure. Wild radish and yellow star thistle growing in flax must be sprayed while still small. This is because the radish plant growing in flax does not develop a slender stem as it does when growing in a denser crop like grain. In flax the radish plant develops a large, protected crown that resists the spray. It must therefore be sprayed in the three-to-five leaf stage or not at all. Black mustard increases greatly in resistance after developing a characteristic smooth, glossy stem, and upper leaves. Spraying should be done before this development. Knotweed, pale smartweed, lamb's-quarters, rough pigweed (*Amaranthus retroflexus*),

tumbling pigweed (*Amaranthus graecizans*), and common chickweed have been effectively controlled only when sprayed in the cotyledon to the 1-inch stage of growth. Yellow star thistle in grain or flax should be sprayed only in the rosette stage of three to six leaves. Prickly lettuce should be sprayed when it has not more than five leaves. Fireweed should be sprayed as a rosette, although good results have been obtained on very succulent plants up to the flower-bud stage.



Fig. 8.—Mustard plants in the proper stages of development for treatment with Sinox. The corresponding sizes of grain plants are shown at the right. (From Bul. 596.)

Conditions Under Which Plants Grow.—The influence of growth conditions such as soil moisture, temperature, and sunlight on the resistance of plants to chemicals has been noted by earlier writers.^{5, 6} Plants with the succulent stems characteristic of good growing conditions are more easily killed than stunted or woody-stemmed plants growing under difficulties. Weeds shaded by dense grain or by foliage are more tender than are the same species when fully exposed to the sun. During February, 1939, the weather in the entire Sacramento Valley was dry, with about one third of the normal rainfall, and with the average relative humidity about two-thirds normal. Where the soil was moist, with good stands of grain, there was no difficulty; but where the soil was dry, with poor, stunted plants, results were unsatisfactory on fireweed, yellow star thistle, and wild radish above the five-leaf stage. Moreover, the rate of action on the wild mustard and young wild radish was greatly retarded. During drought or adverse conditions the cuticle of plants thickens, enabling them to resist drying and the penetration of sprays.

⁵ Bolley, H. L. Weed control by means of chemical sprays. North Dakota Agr. Exp. Sta. Bul. 80:541-74. 1908.

⁶ Aslander, Alfred. Sulphuric acid as a weed spray. Jour. Agr. Research 24(11): 1065-91. 1927.

Temperature and Humidity.—When weeds are young and succulent, good results are obtained under a wide range of temperature and humidity. At low temperatures and under dry conditions, however, the rate of action is much reduced. Rains occurring at such periods will wash Sinox from the leaves of weeds and will reduce the effects of a given treatment, as discussed below.

Rain, Fog, and Dew.—The time required for the Sinox spray to remain on the weed to produce satisfactory results depends upon the rate

TABLE 3

EFFECT OF APPLICATION, TEMPERATURE, WASHING, RAIN, AND GROWTH STAGE OF PLANTS ON CONTROL OF SUCCULENT WILD MUSTARD BY SINOX

Plants in rosette				Plants with stems			
Air temperature, degrees F	Gallons Sinox per acre*	Time before rain	Control, per cent	Air temperature, degrees F	Gallons Sinox per acre*	Time before rain	Control, per cent
45	1.14	7 days	99	43	1.50	12-24 hours	0
48	1.20	5 days	100	48	3.00	2 days	60
50	0.83	7 days	99	52	1.25	1 day	100
52	0.75	3 days	100	57	1.50	4-12 hours	0
55	1.50	½ hour†	20	58	0.75	3 days	85
55	0.75	6 hours	99	58	1.50	3 days	99
56	0.75	4 hours†	75	58	1.20	12-24 hours	poor
56	1.50	4 hours	95	60	1.50	6 hours	20
58	0.66	2½ days	98	60	1.00	2 days	100
60	1.50	1 hour†	10	62	1.00	5 days	100
60	1.50	2 hours†	25	65	1.20	3 days	66‡
60	1.50	6 hours†	90	65	1.00	3 days	99
60	0.66	2 days	90	70	1.00	3 days	97
61	1.33	1½ hours	100	72	1.50	2 days	70
62	0.66	5 days	99	79	1.25	2 days	100
65	1.00	3 days	100	80	0.75	2 days	95

* Figures in this column represent gallons of undiluted Sinox. The amount of dilution is less important than the amount of active material per unit area.

† Washed with hand-spray using a quantity of water equivalent to 0.02 inch rainfall. These plots were 1 rod square.

‡ The low per cent of control in this case reflects the toughness of the mustard plants, which were stunted by alkali.

of action. As described above, the type of action depends upon the conditions in the field at the time of spraying. The effect of washing off, both artificially and by rain, on wild mustard plants of different stages and at various temperatures, is given in table 3. At a temperature of 55° Fahrenheit and higher at the time of application, good results were obtained after the Sinox had remained on the young succulent plants from 2 to 4 hours. At the flower-bud stage, at least 4 hours was required. At low temperatures, 24 to 48 hours was generally needed. Fireweed appeared more exacting than wild mustard and, unless very succulent and

at warm temperatures, Sinox had to remain in contact with the plants from 2 to 4 days for satisfactory results (table 4).

Success has been attained on succulent wild mustard and fireweed when the spray was applied during a heavy fog at 52° Fahrenheit. A rain

TABLE 4
EFFECT OF AIR TEMPERATURE, RAIN, AND GROWTH STAGE OF PLANTS
ON CONTROL OF FIREWEED BY SINOX

Plants in rosette				Plants with stems			
Air temperature, degrees F	Gallons Sinox per acre*	Time before rain	Control, per cent	Air temperature, degrees F	Gallons Sinox per acre*	Time before rain	Control, per cent
48	0.83	5 days	44	43	1.50	3 days	10
48	1.16	5 days	90	56	1.75	4 hours	10
50	1.00	6 days	97	60	2.00	6-12 hours	10
52	0.83	3 days	88	61	1.87	2 days	10
57	0.75	8 days	98	62	1.00	8 days	86
60	1.50	12-24 hours	10	65	0.67	2 days	50
60	1.06	14 days	90	65	1.33	2 days	95
62	1.75	4 hours	10	75	1.33	1 day	95
61	1.33	1½ hours	100	80	2.00	5 days	95

* Figures in this column represent gallons of undiluted Sinox. The amount of dilution is less important than the amount of active material per unit area.

occurred three days after the application. Other sprayings at lower temperatures, 43° F and below, accompanied by a heavy fog followed by rain in 3 days, failed to produce satisfactory results.

Early morning dews at the time of application apparently had no

TABLE 5
EFFECT OF SPRAY PRESSURE ON THE CONTROL OF
WILD MUSTARD

Plot no.	Pressure, pounds	Volume,* gallons per acre	Estimated control, per cent
702.....	60	50	99
703.....	155	35	99
705.....	200	50	99
704.....	300	57	99

* A single concentration, 1 gallon of Sinox in 50 gallons of water, was used throughout.

effect on the final results. In very dry weather, however, dews following the application appeared to have a beneficial effect in speeding up the action.

Spray Pressure.—The question is often asked, What is the best spray pressure to use? According to the general experience in the spraying of

herbicides, the high pressures customary in orchard practice are not necessary for satisfactory results. In the present investigations the spray pressure was often varied from 50 to 100 pounds per square inch. In one series of experiments (table 5) it was varied from 60 to 300 pounds per square inch. No significant differences in results were noted. It was observed, however, that pressures below 75 pounds were noticeably more subject to wind drift, that nozzles were then more easily clogged, and that at very low pressures the angle of spread of the spray fan was often insufficient for complete double coverage. For general field work, any pressure between 75 and 150 pounds per square inch is satisfactory.

DOSAGE WITH GROUND SPRAYERS

Dosages that have given satisfactory results on some of the most common weeds of grain and flax will be noted in tables 1 and 2. On wild and yellow mustards at ideal stages for spraying, good results have been obtained with 1 gallon of Sinox dissolved in 120 gallons of water and applied at the rate of 80 to 100 gallons per acre. A concentration of 1:100 for more advanced stages, up to blossoming, is more satisfactory. On black mustard at the ideal stage and on common vetch 3 to 6 inches high, a 1:100 dilution at 80 to 100 gallons per acre has been satisfactory. Wild radish, fireweed, and yellow star thistle generally require a 1:80 dilution at 80 to 100 gallons per acre for best results. Succulent wild radish growing in dense grain has been successfully controlled when 10 to 24 inches high, 120 gallons to the acre being used at this dilution.

Where the problem of hauling water is difficult, one may greatly reduce the volume of spray per acre by using suitable nozzles and increasing the concentration of Sinox. Highly satisfactory results have been obtained on young, succulent fireweed, wild radish, wild mustard, and black mustard by using 1 gallon of Sinox to 50 gallons of water and applying at the rate of 50 to 60 gallons to the acre. Judging from one experiment (table 5) the volume of spray per acre can possibly be reduced to 35 gallons where a 1:50 concentration is used. Because, however, of insufficient data and of the present mechanical difficulties in the application, such a low volume cannot be recommended.

For knotweed, pale smartweed, rough pigweed, tumbling pigweed, lamb's-quarters, and common chickweed a 1:80 dilution at 120 gallons to the acre is generally required when the weeds are very small—from the cotyledon to the 1-inch stage. Results have been unsatisfactory on these weeds at later stages. Purple thorn apple (*Datura Tatula*) in the one- to two-leaf stage, has been successfully controlled in small ensilage corn with 1:80 dilution at 120 gallons to the acre.

DOSAGE WITH AIRPLANE APPLICATION

The results of some airplane applications for controlling wild mustard and wild radish are given in tables 6 and 7, respectively. The applications were made in swaths of various lengths in different fields. For wild mustard and common yellow mustard at the ideal stages for spraying,

TABLE 6
RESULTS OF AIRPLANE APPLICATIONS OF SINOX IN CONTROLLING
WILD MUSTARD IN GRAIN FIELDS

Field no.	Sinox concentration	Volume, gallons per acre	Growth stage of mustard	Estimated control, per cent
1.....	1:12	15	Stems 12-15 inches, succulent	97
2.....	1:15	15	Stems 3-6 inches, succulent	99
.....	1:15	15	Stems 12-18 inches, succulent	95
3.....	1:10	8	4-7 leaves, succulent	99

the most satisfactory results with airplane application have been obtained by dissolving 1 gallon of Sinox in 14 gallons of water and applying at the rate of 12 to 15 gallons to the acre. As is noted in table 6, however, the applications on wild mustard have usually been on advanced

TABLE 7
RESULTS OF AIRPLANE APPLICATIONS OF SINOX IN CONTROLLING
WILD RADISH IN GRAIN FIELDS

Field no.	Sinox concentration	Volume, gallons per acre	Growth stage of radish	Estimated control, per cent
1.....	1:9	9	3-6 leaves, succulent	75*
2.....	1:10	15	4-6 leaves, succulent	90
.....	1:10	15	7-10 leaves, stunted	40
3.....	1:10	15	4-10 leaves, stunted	95
.....	1:10	15	Stems 4-6 inches, stunted	30
4.....	1:10	15	4-8 leaves, stunted	85
5.....	1:10	15	3-7 leaves, succulent	100

* This low percentage of control was probably caused by inadequate coverage at the edges of each swath. Excellent control was obtained in the center of each swath for a width of about 27 feet. The other applications were made on a swath measuring 27 feet, instead of 35 as in field 1.

stages. Judging from one test (table 6, field 3), the volume per acre could be reduced to 8 or 10 gallons on four-to-seven leaf mustard. For wild radish, 1 gallon of Sinox is dissolved in 9 gallons of water and applied at the rate of 12 to 15 gallons per acre. The results on wild radish (table 7) show that best success is obtained when the plants are succulent, with no more than seven leaves. Those plants which were not

killed were severely stunted from the effects of the spray. The plane must fly low at a height of about 5 to 6 feet. Figure 9 shows an airplane spraying Sinox on grain.



Fig. 9.—An airplane spraying Sinox on grain.

The use of the airplane for control of certain common weeds of flax has not been successfully worked out. In one test wild mustard was killed without injury to the flax, whereas fireweed, which requires a higher dosage, was controlled only with considerable damage to the crop.

TOLERANCE OF GRAIN AND FLAX TO SINOX

Both grain and flax have been sprayed under many different conditions and with varying dosages. There is apparently no danger of injuring grain at any practical dosage used in the field. Barley and wheat have been sprayed at all stages, including the boot stage, with no serious injury or setback. In some experiments on barley, where an extreme dosage of 1:30 dilution at the rate of 320 gallons was applied, the barley was shortened about 1 inch. Where the grain is rank and grassy, a slight tipburn will be noted a few days after the application. The material can be used with safety where the growing season is short, as is indicated by its success in the Tule Lake region of Siskiyou County.

With flax, however, which is less tolerant than grain, some precautions should be observed. Judging from various tolerance tests on Punjab flax (table 8) the upper limit of safety on young, slender-stemmed flax, in the cotyledon to 6-inch stage, and growing in the shade of a heavy weed infestation, is a dosage represented by $1\frac{1}{4}$ gallons of Sinox per acre. The volume of spray per acre does not in itself appear important between the range of 60 and 100 gallons to the acre. Higher dosages than

TABLE 8
TOLERANCE OF PUNJAB FLAX TO SINOX

Field no.	Air temperature, degrees F	Growth stage of flax	Sinox concentration	Volume, gallons per acre	Injury
1	52	2-4 inches in fireweed, exposed to sun....	1:80	140	None
	52	1-3 inches in wild mustard, shaded.....	1:80	120	11 per cent thinning
	50	2-4 inches in fireweed, exposed to sun....	1:50	50	None
	52	2-4 inches in fireweed, exposed to sun....	1:10	8	None
	52	2-4 inches in fireweed, exposed to sun....	1:5	8	40 per cent thinning
2	58	1-2 inches in wild mustard, slender stems, exposed to sun.....	1:60	60	None
			1:60	90	Severe
			1:80	80	None
			1:80	120	10 per cent thinning
			1:100	100	None
3	65	Cotyledons to 4 inches, in wild mustard, stunted, exposed to sun.....	1:60	120	None
4	72	1-3 inches, in wild mustard, stunted, exposed to sun.....	1:80	120	None
5	65	8 inches in fireweed, shaded.....	1:60	320	Slight
			1:40	160	20 per cent thinning
			1:40	320	50 per cent thinning
			1:30	160	50 per cent thinning

those represented by $1\frac{1}{4}$ gallons of Sinox per acre are permitted where the crop is not heavily shaded or where the stems of the flax plants are fairly strong. No information is available to show how Sinox affects flax in blossom, since it would appear impractical to spray at this period or later.

The type of injury caused by excessive dosages of Sinox on flax has a particular interest. Often the spray is observed to run down the stem and collect at the base near the surface of the ground. Later the stem in this region is constricted. The damage is not apparent until 7 to 14 days after the application, when the injured plants lodge from lack of support and wilt from lack of moisture. Occasionally the constriction occurs near the tip of the plant just under the terminal bud.

Flax trampled by wheels or tracklayers just before being sprayed is severely injured and often killed by Sinox. Grain is less severely injured and will eventually recover. The damage from crushing is lessened considerably if the boom covering the wheel tracks is placed in front of the equipment instead of in the rear. The explanation is that little spray adheres to normal grain or flax plants, since they are not easily wetted, and consequently but little chemical ever comes in contact with the mechanically injured areas. Less injury was obtained on flax by one contractor whose spray rig and tracklayers did not follow the same path, even though the boom was attached to the rear.

USES OF SINOX OTHER THAN WITH CEREALS AND FLAX

Transplanted Onions.—Spraying has proved practical where the principal weed problem in transplanted onions results from various species of mustard, prickly lettuce, wild radish, common sow thistle (*Sonchus oleraceus*), knotweed, smartweed, fireweed, very small chickweed, shepherd's purse (*Capsella Bursa-pastoris*), red maids (*Calandrinia caulescens* var. *Menziesii*), young bur clover (*Medicago hispida*), mayweed (*Anthemis Cotula*), wart cress (*Coronopus didymus*), and various pigweeds (*Amaranthus* spp.). Where, however, the weed problem consists of various grasses, miner's lettuce (*Montia perfoliata*), purslane (*Portulaca oleracea*), or any weed which, because of its growth stage or nature cannot be killed, then spraying should not be undertaken. The onions should be healthy and not over 10 inches high. The weeds must be small. Knotweed, smartweed, common chickweed, and the various pigweeds must be sprayed before branching develops. Best results, with a knapsack sprayer on mixed infestations of these weeds, have been from Sinox at the rate of 1 gallon to 60 gallons of water, applied at the rate of 160 gallons per acre (table 9).

Where the material is applied with a power sprayer (fig. 10) the volume per acre can, no doubt, be reduced to 120 gallons. Also, where only mustards or other susceptible species are present the concentration could probably be reduced. Young transplanted onions, once established, are very tolerant of the spray.

Seedling Onions.—Since young onions from seed have been killed with Sinox, spraying cannot at present be recommended for them.

Peas.—Peas 2 to 4 inches high were not injured by 160 gallons per acre of a 1:120 dilution. The same volume of a 1:60 dilution, however, injured many plants and killed some outright. Peas infested with mus-

tards or other weeds controllable with the lower concentration can probably be sprayed with safety; but because of insufficient experimental data, no definite recommendations can be made.

Corn.—Purple thorn apple in ensilage corn has been a problem on the Bianchi & Grande dairy ranch at Point Reyes station in Marin County. Ensilage containing this weed is not readily eaten by cattle. In

TABLE 9
RESULTS OF APPLICATIONS OF SINOX FOR CONTROLLING WEEDS
IN TRANSPLANTED ONIONS

Weed	Stage	Concentration of Sinox	Volume, gallons per acre	Estimated control, per cent
Wild radish.....	3-4 leaves.....	1:120	160	99
Wild mustard.....	3-5 leaves.....	1:80	120	95*
Wild lettuce.....	4-5 leaves.....	1:80	160	99
Wild lettuce.....	5-6 leaves.....	1:60	160	99
Shepherd's purse.....	Early rosette.....	1:120	160	99
Fireweed.....	Early rosette.....	1:120	160	95
Knotweed.....	Cotyledons.....	1:80	160	80
Knotweed.....	1-3 inches.....	1:60	160	95
Wart cress.....	Rosette.....	1:60	160	99
Volunteer sugar beets.....	4-6 leaves.....	1:80	160	99
Red maids.....	Early rosette.....	1:120	160	99
Tumbling pigweed.....	2-3 inches.....	1:120	160	80
Tumbling pigweed.....	2-3 inches.....	1:60	160	99
Common chickweed.....	Cotyledon to 1 inch (un-branched).....	1:80	160	99
Common chickweed.....	Branched and bloom.....	1:60	180	0
Miner's lettuce.....	In bloom.....	1:60	160	20
Purslane.....	Branched.....	1:40	160	0
Grasses.....	1-3 inches.....	1:60	160	0

* Rain occurred one hour after application. This application was made with a power sprayer.

experimental plots, where a 1:80 dilution at 120 and 240 gallons per acre were applied, the control of purple thorn apple 1 to 3 inches high was 95 and 100 per cent, respectively. There was no injury to the corn, which was 3 to 5 inches high. The entire field of about 10 acres was later sprayed commercially at the higher rate.

Alfalfa.—Seedling alfalfa is too tender to be sprayed with safety. Judging from outdoor pot tests, however, the resistance increases greatly with age, so that stands over six weeks old, 2 to 4 inches in height, will tolerate a 1:80 dilution at 160 gallons per acre. Well-established stands will tolerate 1:80 dilution at 300 gallons to the acre without serious injury or setback. According to some field tests (table 10), yellow star thistle, sometimes a problem in alfalfa, can be killed out successfully in well-established stands. Good results were obtained only where the thistles were growing in severe competition, causing their leaves to grow

upright. Thistles growing as flat rosettes were not satisfactorily controlled.

Roadsides, Fence Lines, and Pastures.—In the Sacramento Valley and in some coastal counties, there is considerable interest in controlling yellow star thistle along roadsides, along fence lines, and in pastures. Tests and demonstrations were carried out in both 1938 and 1939 (table 11).

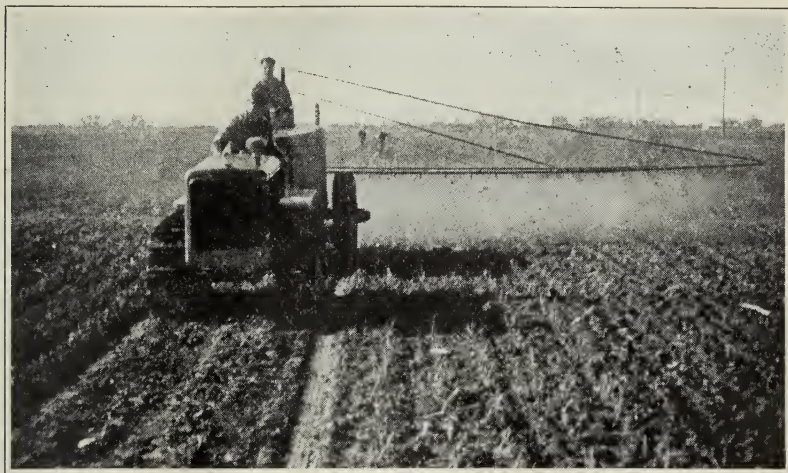


Fig. 10.—Spraying transplanted onions with Sinox. Note the sprayer traveling in the row left vacant for an irrigation "spud" ditch. The boom covers approximately one half of the area between the vacant rows.

As will be noted in the table, Sinox will readily kill out slender-stemmed plants or plants in the rosette stage whose leaves are growing upright. Sinox at a dilution of 1 gallon to 80 gallons of water, applied at the rate of 240 to 300 gallons per acre, has given best results. Where, however, the thistles are competing with high, dense grass, good results have been obtained with a lesser concentration consisting of 1:100 at 480 gallons to the acre.

Spraying should be done while good growing conditions prevail. Yellow star thistles shaded by dense grass or other foliage proved much more tender than those growing in thin stands. This plant, when having large crowns close to the surface of the ground, as occurs near the edge of a road or where vegetation is thin, was not satisfactorily controlled. Where this condition exists along roadsides, disking or scraping as far out from the edge of the road as possible is apparently more practical than spraying. When this is done, a shoulder of various widths bordering the fence line remains where spraying is satisfactory.

Milk thistle (*Silybum Marianum*) in the rosette stage is successfully

controlled with 1 gallon of Sinox to 80 gallons of water applied at the rate of 300 to 400 gallons per acre. Milk thistle is particularly a problem along fence lines and canal banks in the Sacramento Valley.

Livestock should not be confined on pastures recently sprayed with Sinox, although small patches of thistle in pastures have been sprayed in the presence of cattle and sheep without ill effects.

Lawns.—At Davis, in some cases, common dandelion (*Taraxacum vulgare*), common plantain (*Plantago major*), and crabgrass growing in bluegrass lawns have been successfully controlled with Sinox. The

TABLE 10
RESULTS OF SINOX APPLICATIONS FOR CONTROLLING YELLOW STAR THISTLE
IN ESTABLISHED STANDS OF ALFALFA

Location	Sinox concentration	Volume, gallons per acre	Height of thistle	Height of alfalfa	Control, per cent
Lake County.....	{ 1:80	160	6-12 inches	12-18 inches	95
	{ 1:80	200	6-12 inches	12-18 inches	99
	{ 1:80	300	6-12 inches	12-18 inches	99
	{ 1:80	400	6-12 inches	12-18 inches	99
Colusa County.....	{ 1:100	160	Flat	Crowns	50
	{ 1:80	200	Flat	3-6 inches	10

results on dandelion for 1938 and 1939 appear in table 12. Two applications of a 1:20 dilution by volume were required to kill dandelions successfully when used at the rate of $\frac{3}{4}$ gallon per 100 square feet. The first application was made on April 1; the second, 27 days later, when the dandelions had again developed full foliage. The lawn was watered three days after the applications. Other tests in which the lawn was watered 1 day after the application failed to give satisfactory control (table 12). Where a heavy infestation of dandelion has been killed out, it is desirable to reseed; otherwise crabgrass or dandelion seedlings may occupy the bare areas.

Common plantain was successfully controlled with two applications of a 1:28 dilution used at the rate of 1 gallon per 100 square feet. The applications were made in April, 18 days apart.

Spraying for dandelion and plantain must be done on lawns before the hot weather to avoid severe burning of the lawn grasses. Established stands of Bermuda grass, Kentucky bluegrass, and mixtures containing Kentucky bluegrass, ryegrass, and redtop have shown considerable tolerance to the spray during the cool months. A slight browning of the grass occurs after the application and will persist for about 14 days.

Bent grasses and other varieties that mat down close to the surface of the ground will not, however, tolerate the high dosages under conditions prevailing in the central valleys.

The results of tests conducted at Davis in 1938 and 1939 for con-

TABLE 11
RESULTS OF SINOX APPLICATIONS FOR CONTROLLING YELLOW STAR THISTLE
IN PASTURES AND ALONG ROADSIDES

Location, county	Sinox concentration	Volume, gallons per acre	Soil con- dition	Density of foliage	Height of grass, inches	Growth stage of thistle	Height of thistle, inches	Esti- mated control, per cent
Solano.....	{ 1:120	160	Moist	Dense	2-3	Rosette	2-3	99
	{ 1:120	320	Moist	Dense	12-24	Stem	4-12	50
	{ 1:120	480	Moist	Dense	12-24	Stem	4-12	99
	{ 1:60	320	Moist	Dense	12-24	Stem	4-12	85
	{ 1:60	480	Moist	Dense	12-24	Stem	4-12	100
Yolo.....	1:80	400	Moist	Dense	24-36	Stem	4-8	99
Alameda.....	1:80	260	Moist	Thin	2-5	Rosette	3-5	91
San Joaquin.....	1:80	320	Moist	Dense	4-7	Rosette	2-3	99
Lake*.....	{ 1:80	160	Dry	Dense	1-2	Rosette	2-4	20
	{ 1:80	240	Dry	Dense	1-2	Rosette	2-4	75
	{ 1:80	300	Dry	Dense	1-2	Rosette	2-4	99
Tehama.....	{ 1:100	265	Very dry	Moderate	4-6	Rosette	3-5	80
	{ 1:80	240	Dry	Moderate	4-6	Rosette	3-5	85
	{ 1:60	240	Dry	Moderate	4-6	Rosette	3-5	99
	{ 1:60	240	Dry	Thin	None	Rosette	Flat	65
Colusa.....	{ 1:80	240	Dry	Dense	None	Rosette	4-6	65
	{ 1:80	300	Dry	Dense	None	Rosette	4-6	90
	{ 1:80	160	Moist	Dense	6-7	Rosette	4-6	70
	{ 1:80	300	Moist	Dense	6-7	Rosette	4-6	99
Glen.....	{ 1:80	300	Dry	Thin	None	Rosette	Flat	45
	{ 1:80	300	Dry	Dense	3-5	Rosette	4-6	94
Butte.....	{ 1:100	240	Dry	Dense	6-7	Rosette	3-5	80
	{ 1:80	160	Dry	Dense	6-7	Rosette	3-5	65
	{ 1:80	240	Dry	Dense	6-7	Rosette	3-5	97
	{ 1:80	240	Dry	Thin	None	Rosette	Flat	60
Sacramento.....	1:100	480	Dry	Dense	4-6	Rosette	3-5	99
Yuba.....	{ 1:100	240	Dry	Thin	2-3	Rosette	2-3	75
	{ 1:80	240	Dry	Dense	4-6	Rosette	3-5	95

* Pasture land; all others roadside.

trolling crabgrass in lawns are recorded in table 13. As will be noted, there are two columns for the percentage control. One column gives a percentage control as shown by counts of dead and live plants approximately 10 days after the application. The other column gives a percent-

age control as shown in the fall after the growing season of the crabgrass has ended. The values recorded in the latter column are based on the percentage of area covered by the crabgrass in the sprayed plot as compared with the unsprayed. The differences in control shown in the two columns are explainable because, in some tests, germination of crabgrass seed occurred after the spray application and also because the few plants not killed by the spray will spread out and occupy a relatively large area of the lawn. As will be observed, a 1:33 dilution by volume,

TABLE 12
RESULTS OF SPRAYING DANDELIONS IN BLUEGRASS LAWNS AT DAVIS

Sinox concentration	Volume, gallons per 100 square feet per application	Number of applications	Time between applications, days	Days after first application before irrigating	Days after second application before irrigating	Estimated control, per cent	Approximate time required for full recovery of bluegrass, days
1:20.....	$\frac{3}{4}$	2	27	10	10	99	20
1:25.....	$\frac{3}{4}$	2	23	7	7	75	40*
1:25.....	1	2	23	7	7	85	40*
1:20.....	$\frac{3}{4}$	1	..	10	..	0	14
1:20.....	$\frac{3}{4}$	2	23	3	1	0	14
1:15.....	1	1	23	10	..	0	20

* This lawn was in a poor state of fertility, a fact that may account for the long period before recovery.

applied at the rate of $\frac{3}{4}$ to 1 gallon per 100 square feet, gave an excellent kill of the young seedlings; but germination following the application often caused poor final results. As the table indicates, the degree of germination following the application was influenced by two factors: first, the date of application; second, the condition of the lawn grass at the time of the application and thereafter. All tests made before April 10 in Davis in 1939 had little success; and applications where the lawns were very thin, with bare spots, or where lawn grasses were severely burned out by excessive dosages of spray gave poor final results. Likewise, where bent grass was present and had been killed out, crabgrass actually became more of a problem after spraying than before, because late germination resulted from the thinning. The latest date for successful application varied according to the development of the weed. Plants with more than three leaves were not readily killed by the spray. Considering the importance of the germination period, the lawn might well be watered heavily during the week before it is to be sprayed when seedlings are first appearing. It should not be watered again for at least 3 days after the application. The few remaining plants not killed by the spray should be pulled by hand. Where the lawn is very thin, with bare

TABLE 13
CONTROL OF CRABGRASS SEEDLINGS IN LAWNS BY SINOX AT DAVIS

Sinox [concentra- tion	Volume, gallons per 100 square feet	Date of application	Density of grass before application	Condition of lawn grasses after application	Degree of germination after application	Control, per cent	Area covered by crabgrass, per cent*
1:25	1.00	April 5, 1939	Moderate	Recovered in 10 days.....	Considerable	..	50
1:50	1.00	April 5, 1939	Moderate	Recovered in 10 days.....	Considerable	..	90
1:28	1.00	April 10, 1938	Thin	Recovered in 10 days, followed by stimulation.....	None	99	5
1:28	1.00	April 13, 1938†	Thin	Temporary thinning, followed by recovery and stimulation.....	None	99	4
1:28	1.00	April 13, 1938	Thin	Recovered in 10 days.....	Slight	99	38
1:50	1.00	April 13, 1938	Thin	Recovered in 10 days.....	Very slight	99	25
1:19	1.00	April 13, 1938	Thin	Serious thinning.....	Considerable	80‡	88
1:33	1.00	April 15, 1939	Thin	Bent grass killed.....	Considerable	95‡	90
1:40	0.50	April 19, 1939	Bare spots	Reseeded.....	Considerable	90‡	50
1:33	0.75	April 19, 1939	Moderate	Recovered in 10 days.....	Very slight	99	10
1:33	1.00	April 21, 1939	Bare spots	Very thin with bare spots.....	Considerable	..	100
1:33	1.00	May 5, 1939	Thin	Recovered in 10 days; thin.....	Slight	90‡	75
1:33	1.00	May 9, 1938	Thin	Grass thinned 25% but recovered; stimulation followed.....	Slight	99	35

* This percentage is based on a comparison with untreated areas, as estimated in the fall after the crabgrass was mature.

† There were two applications, the second being on April 27, 1938.

‡ Plants with more than three leaves were not killed. This was a very heavy infestation.

¶ A few plants were protected by tufts of lawn grass.

areas, one might also fertilize and reseed the preceding season before attempting to control crabgrass with a spray.

Deep-Rooted Perennials and Puncture Vine.—Sinox apparently has no practical place under California conditions in eradicating such deep-rooted perennials as wild morning-glory (*Convolvulus arvensis*), the hoary cresses (*Lepidium Draba*, *L. Draba* var. *repens*, *Hymenophyllum pubescens*), Russian knapweed (*Centaurea repens*), Klamath weed (*Hypericum perforatum*), Johnson grass (*Sorghum halepense*), poison oak (*Rhus diversiloba*), and Bermuda grass (*Cynodon Dactylon*). It might, however, be used in special cases to prevent seed formation by certain of the broad-leaved perennials in seed and hay crops. Since puncture vine (*Tribulus terrestris*) is highly resistant to Sinox, control has not been attained by any reasonable dosage.

EFFECT OF SINOX ON THE SOIL⁷

To determine whether the amounts of Sinox used in spraying might have an effect through the soil, experiments were carried out under controlled conditions in the greenhouse. Soils in cans were mixed with varying amounts of the chemical and then seeded with oats. This was done with various soil types representing several soil series. A slight stimulation of growth, as measured by fresh weight of plants, occurred in some soils at concentrations around 15 parts per million on an air-dry-soil basis. Assuming 90 pounds per cubic foot as an average weight for dry soil, 15 ppm is roughly equivalent to 3 gallons of undiluted Sinox per acre in the surface 6 inches. Growth was definitely reduced with 40 ppm in most soils. This represents about 8 gallons per acre in the surface 6 inches.

Growth was completely inhibited by concentrations of 100 to 500 ppm, according to the soil type. These concentrations are equivalent to 19½ and 98 gallons of undiluted Sinox per acre per 6 inches of soil, respectively.

This toxic effect in soil soon wears off; and, in the greenhouse tests, concentrations at first definitely injurious gave marked stimulation a few months later. The material probably decomposes in the soil, reducing the effective concentration. The stimulation is probably not due to the nitrogen contained in combination in the dinitro-ortho-cresol molecule, since this amounts to only about 0.21 pound per gallon. The most likely hypothesis is that stimulation is due to the effect on soil organisms, producing a "partial sterilization," like disinfectants and anaesthetics.

Apparently, then, dosages ordinarily used in spraying crops have no

⁷ This summary is based on unpublished data contributed by Dr. A. S. Crafts.

injurious action through the soil; the effect, if any, at these low dosages is beneficial. In fact, stimulation as evidenced by better color has occasionally been observed in cereals sprayed with Sinox.

EQUIPMENT FOR APPLYING SINOX

Pump.—The most critical part of any spray equipment is the pump. Its selection depends on various requirements and is often a matter of meeting a grower's own particular problem. Of the four different types of pumps used by growers for spraying flax and grain during the past season, the most common was the reciprocating or plunger type. Three of these were ordinary orchard sprayers with high-pressure pumps. (See



Fig. 11.—An orchard sprayer mounted on a trailer.

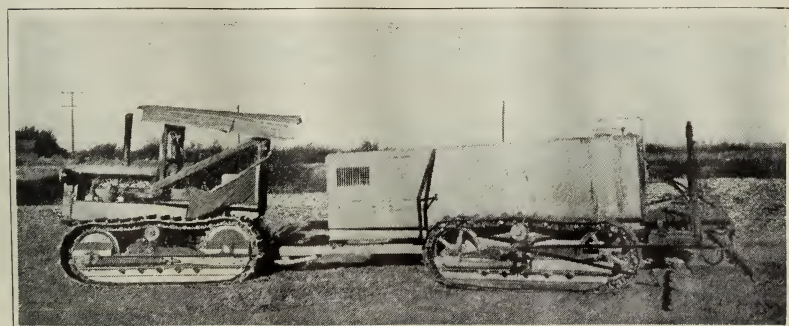


Fig. 12.—An orchard sprayer equipped for field spraying, mounted on tracks.

figs. 11 and 12.) Others of the plunger type were designed for pressures lower than those commonly used in fruit-tree spraying. The low-pressure plunger type would appear more nearly ideal for general use. If, however, the grower can obtain a good secondhand orchard sprayer, the cost of high-pressure equipment will not be a disadvantage. When such pumps are used, however, the relief valve should be adjusted to a pressure between 75 and 150 pounds.

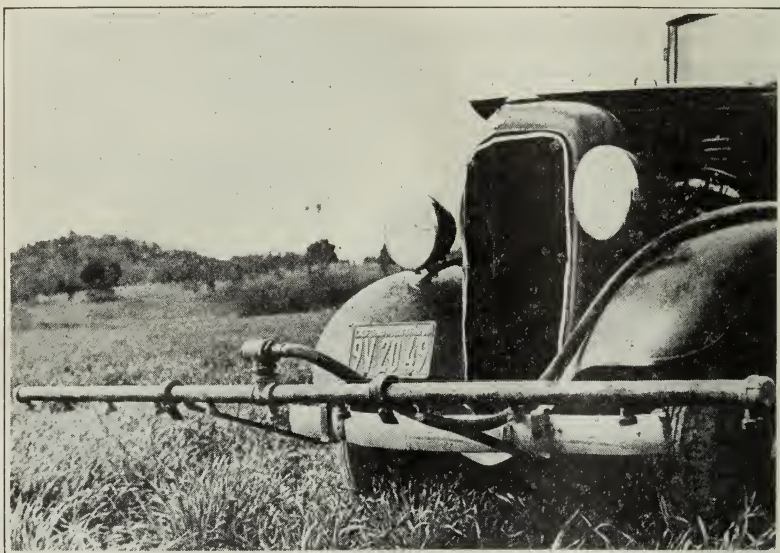


Fig. 13.—A pickup truck equipped for spraying grain fields. Note the boom attached to the front bumper and the pump mounted on the motor. Rubber hoses carry the spray from the tank in the rear to the pump, and from the pump to the boom. (Photograph by H. L. Washburn.)

One type used during the season for spraying grain consisted simply of a pickup truck fitted with a special type of pump run from the fan belt of the motor (fig. 13). Some of these pumps can also be run by a power take-off from the transmission. These are inexpensive and practical outfits where the ground will support this type of carriage and where the spray water is free of grit. These pumps may also be attached to the engines of tractors. One should note, however, that the engines of some trucks when running in low gear or in compound low gear at 3 to 5 miles per hour will not turn over fast enough to develop the full capacity of the pump. Sometimes, therefore, only a short boom can be used unless special devices are installed to increase the speed of the pump pulley.

One grower used a high-pressure centrifugal pump made of special metal called Durimet. This was designed for spraying acid solutions.

Since Sinox is noncorrosive, the special metal is not necessary. A similar pump made of cast-iron would cost less and would be equally serviceable. The usual type of single-stage centrifugal pump does not develop sufficient pressure for best performance.

The required capacity of the pump will depend upon the length of the boom used. Where 80 to 120 gallons of spray is applied to the acre, one should allow about $\frac{9}{10}$ gallon per minute for each foot length of boom.

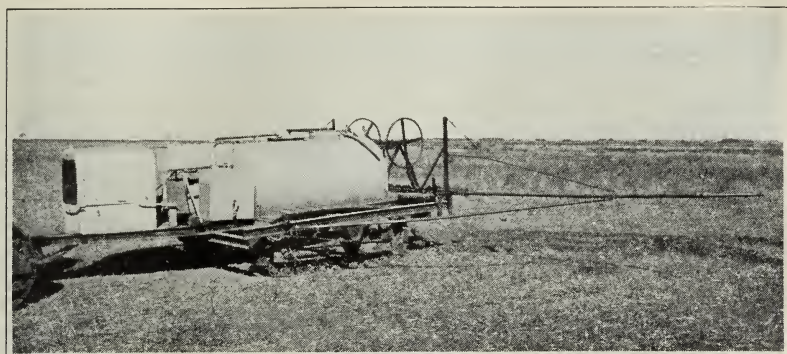


Fig. 14.—A sprayer originally designed for sulfuric acid (ejector mixing), converted to spraying Sinox by removing the ejector and the side tube. Note supports and braces for the boom.

Where much smaller volumes per acre are contemplated, the pump capacity need not be so great. It should always slightly exceed any expected requirements.

Boom.—Booms should be made of extra-thick $1\frac{1}{4}$ inch black iron pipe. They usually have three sections, one for each side and one covering the wheel tracks. The sections extending out from each side of the rig must be supported both vertically and horizontally by diagonal braces (figs. 12 and 14). These sections are attached to the body of the sprayer in such a manner as to conveniently permit a vertical adjustment and to allow the sections to swing forward when the sprayer is being hauled to and from the field.

The length of the boom will depend upon the topography of the ground to be sprayed. Under ideal conditions 32 feet is about the maximum total length that can be handled conveniently without tiller wheels (fig. 15) or special devices for quickly raising or lowering the ends of the boom. The usual height at which the boom level is maintained above the ground is 24 to 33 inches.

Nozzles and Spray Disks.—The type of nozzle most efficient for spraying weeds is one that delivers a fan-shaped or sheetlike spray instead of

a conical spray. Two of these are illustrated in figure 16. The spacing of the nozzles on the boom will depend upon the angle of spread of the spray delivered through the disk of the nozzle. Disks that deliver the spray at an included angle of 60 degrees should be spaced 1 foot apart. Those that produce an angle of spread of 80 degrees can be placed 18 inches apart, and those producing a 90-degree angle can be placed 2 feet apart. These spacings provide for overlapping of fans from adjacent



Fig. 15.—A sprayer with boom attached to one side, illustrating the use of a tiller wheel to support the outer end.

nozzles half their width, giving double coverage of the sprayed vegetation. It is advantageous to use disks whose angle of spread will permit a wide spacing of nozzles on the boom: the large orifices and high pressure will lessen the danger of nozzle-clogging. Where 50 to 80 gallons are applied to the acre, the nozzles should be not less than 18 inches apart. Where higher volumes are employed, the spacing is less important.

The nozzles are screwed on to $\frac{1}{4}$ -inch "short" nipples tapped into the boom. When a boom made of $1\frac{1}{4}$ -inch pipe is being tapped for nipples, it is best to stagger the holes about $\frac{1}{8}$ inch on alternate sides of a center line.

The diameter of the disk orifice will depend essentially upon the various ranges in volume per acre that will be used and also upon the spacing of the nozzles on the boom. The orifice size, the discharge per nozzle, the spray pressure and speed necessary to deliver any volume of spray per acre from 50 to 120 gallons are given in table 14. From the table one can select such combinations of speed, pressure, and disk size as will apply to his particular conditions. The pressures given are only approximations, since disks of different manufacture and design will vary. The spray pressure should always be adjusted to produce the required discharge in gallons per minute per nozzle.

TABLE 14
CALIBRATION TABLE FOR DELIVERING SPRAY AT VARIOUS SPEEDS AND VOLUMES

Volume, gallons per acre	Speed, miles per hour	Nozzles 1 foot apart; 60° angle of spread				Nozzles 1½ feet apart; 80° angle of spread				Nozzles 2 feet apart; 90° angle of spread			
		Required discharge per nozzle, gallons per minute	Drill-number size of orifice*	Pressure, pounds†		Required discharge per nozzle, gallons per minute	Drill-number size of orifice	Pressure, pounds†		Required discharge per nozzle, gallons per minute	Drill-number size of orifice	Pressure, pounds†	
50	3.0	0.30	..	..		0.45	57	70		0.60	56	90	
	3.5	0.35	..	..		0.52	56	66		0.70	56	120	
	4.0	0.40	..	..		0.60	56	90		0.80	56	135	
	4.5	0.45	57	70		0.68	56	115		0.90	53	85	
	5.0	0.50	57	85		0.75	56	135		1.00	53	105	
60	3.0	0.36	..	..		0.54	56	75		0.72	56	125	
	3.5	0.42	57	60		0.63	56	95		0.84	53	75	
	4.0	0.48	57	80		0.72	56	125		0.96	53	95	
	4.5	0.54	56	74		0.81	56	155		1.08	53	125	
	5.0	0.60	56	88		0.91	53	85		1.20	51	95	
80	3.0	0.48	57	75		0.72	56	125		0.96	53	100	
	3.5	0.56	56	75		0.84	53	75		1.12	51	85	
	4.0	0.64	56	100		0.96	53	95		1.28	51	110	
	4.5	0.72	56	125		1.08	53	125		1.44	51	140	
	5.0	0.80	56	155		1.20	51	95		1.60	47	105	
100	3.0	0.60	56	90		0.90	53	85		1.20	51	95	
	3.5	0.70	56	120		1.05	53	120		1.40	51	135	
	4.0	0.80	56	155		1.20	51	95		1.60	47	105	
	4.5	0.90	53	85		1.35	51	125		1.80	47	135	
120	3.0	0.72	56	120		1.08	53	125		1.44	51	140	
	3.5	0.85	53	75		1.27	51	120		1.70	47	120	
	4.0	0.96	53	95		1.44	51	140		1.92	47	155	

* Blank spaces indicate that orifice size is too small in that range or that pressure is too low for practical use.

† These values are only approximate. Disks of different manufacture vary. Pressure should be adjusted to obtain the necessary discharge.

Screens.—Adequate screening of the water refill line and nozzles will save considerable time in spraying by eliminating clogged nozzles. Where water is taken from shallow ditches containing much fine material, the most effective strainers have been the large bonnet type containing three layers of screen, the innermost of which is 80 meshes to the inch. Each nozzle should be provided with a strainer or with a little steel wool or brass turnings.

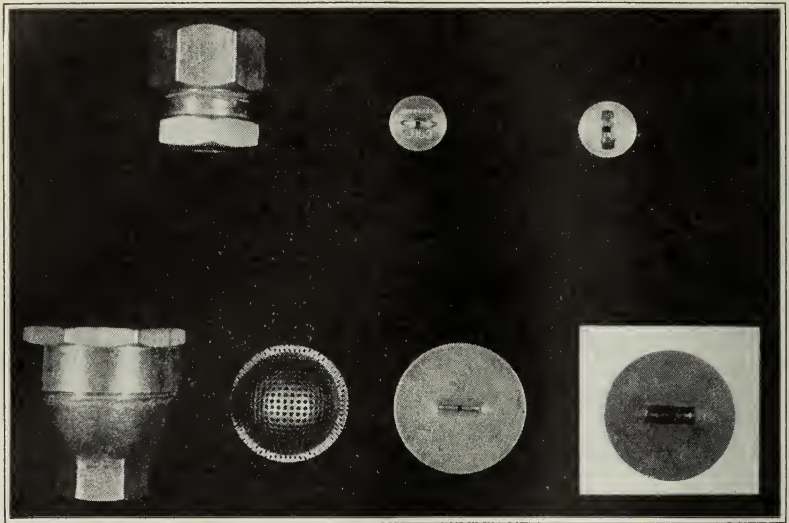


Fig. 16.—Two types of nozzles that deliver the flat-fan type of spray. (Upper, courtesy of the Sutter Orchard Supply Company, Yuba City; lower, courtesy of the John Bean Manufacturing Company, San Jose.)

Tank.—The tank may be made of either wood or steel. The usual capacity is 600 to 800 gallons. The tank should be provided with a deep strainer box through which the Sinox is washed in the refilling process. The strainer should be made of screen with approximately 20 meshes to the inch.

Agitator.—No agitator is required where the Sinox is dissolved by washing the material into the tank through the strainer box, as described above.

COST OF APPLYING SINOX

Various factors determine the expense to the grower of spraying grain or flax. Among these are the cost of the Sinox, the stage and kind of weed, the availability of water, the number of acres sprayed per day, and the cost of labor and machinery. For wild mustard, in general, $\frac{2}{3}$ to 1 gallon of Sinox is required per acre, costing \$1.35 to \$2.00 per acre based

on the 1939 price of Sinox on the Pacific Coast. For wild radish, yellow star thistle, and fireweed, the cost of material will generally run higher, from \$2.00 to \$3.00 per acre, according to the dosage required.

The number of acres sprayed per day will vary with the kind of equipment, the availability of water, the tractor speed, and the length of the boom. From 8 to 10 acres per hour is not uncommon.

The contractor's price for applying Sinox with ground rigs has varied from \$1.00 to \$1.50 per acre for machinery and labor. For airplane, the 1939 price was \$1.65 per acre. Where a grower owns and operates his own equipment, the cost of labor, gas, and oil has been estimated at 50 cents per acre. This does not include allowances for depreciation and upkeep of equipment.

The total cost of treatment on mustard, obtained by adding cost of material and cost of application, varies between a minimum of \$1.85 and a maximum of \$3.50 per acre. The total cost on wild radish, fireweed, and yellow star thistle varies between \$2.50 and \$4.50 per acre.

SUMMARY

Sinox (sodium dinitro-ortho-cresylate) is a noncorrosive, relatively non-hazardous selective herbicide used for controlling certain common broad-leaved annual weeds of cereals, flax, onions, alfalfa, corn, roadsides, and pastures. It is applied as a dilute solution with sprayers (hand or field types) or with specially equipped airplanes.

The dosage for mustards is 1 gallon of Sinox in 120 gallons of water, applied at the rate of 80 to 100 gallons to the acre when the mustard plants have developed three to seven leaves (are approximately 3 to 7 inches high). Wild radish, fireweed, and yellow star thistle, growing in grain and flax, generally require a 1:80 concentration applied at the rate of 80 to 100 gallons to the acre. One may reduce the volume of spray required to 50 gallons per acre by increasing the concentration of Sinox to 1 gallon in 50 gallons of water.

For airplane applications on wild mustard, 1 gallon of Sinox is dissolved in 15 gallons of water and applied at the rate of 12 to 15 gallons per acre. On wild radish in the three- to seven-leaved stages, 1 gallon of Sinox in 10 gallons of water, applied at the rate of 12 to 15 gallons per acre, gives satisfactory results.

Yellow star thistle growing as upright rosettes or with slender stems in alfalfa, or along roadsides and fence lines, or in pastures is killed by using 1 gallon of Sinox to 80 gallons of water applied at the rate of 200 to 300 gallons to the acre. Yellow star thistle growing as large flat rosettes in thin vegetation is not successfully controlled.

Established transplanted onions may be sprayed with safety until they are approximately 10 inches high. Seedling onions are not sufficiently tolerant of Sinox to permit spraying. Common dandelion, common plantain, and crabgrass have been successfully controlled in bluegrass lawns. Further experiments are needed, however, before definite recommendations can be made.

The length of time that the Sinox spray should remain on the weed depends upon the rate of penetration. On young, succulent mustard plants, with air temperatures of 55° Fahrenheit and above, the spray must remain on the plants from 2 to 4 hours before being washed off by rain. On advanced stages of mustard, 24 to 48 hours is generally required. Fireweed, unless very succulent, needs 2 to 4 days. Weeds with succulent stems, characteristic of good growing conditions, are more easily killed than stunted or more woody-stemmed plants growing under adverse conditions.

The material has no injurious effect on the soil at the dosages usually required for satisfactory control.

The total cost of applications of Sinox in controlling wild mustard with ground rigs varied, in 1939 from about \$1.85 to \$3.50 per acre, according to the dosage required and upon the cost of application. For wild radish, yellow star thistle, and fireweed the total cost varied from about \$2.50 to \$4.50 per acre. For airplane application the cost in 1939, was \$3.65 and \$4.65 for applications on wild mustard and wild radish, respectively.

ACKNOWLEDGMENTS

The authors are grateful to Dr. W. W. Robbins and Dr. A. S. Crafts of the Botany Division for assistance in the organization and conduct of the work herein reported, and to Mr. Jack Matley for his assistance in carrying on the field work. We wish to thank the Caterpillar Company and the Campbell-Budlong Company for furnishing equipment used in the 1939 experiments. We are indebted to the Hawke Dusting Corporation, the Independent Crop Dusting Corporation, and A. E. Mahoney, Agricultural Commissioner of San Joaquin County, for assistance in obtaining data on airplane applications.